Chapter 5. Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital ecological functions in wide ranging capacities (Snelgrove et al. 1997). For example, some species decompose organic material as a crucial step in nutrient cycling; other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are sensitive to such changes and rarely occur in impacted areas, while others are opportunistic and can persist under altered conditions (Gray 1979). Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since many animals in these assemblages are relatively stationary and long-lived, they can integrate the effects of local environmental stressors (e.g., pollution or disturbance) over time (Hartley 1982, Bilyard 1987). Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which are often designed to document both existing conditions and trends over time.

Overall, the structure of benthic communities may be influenced by many factors including depth, sediment composition and quality (e.g., grain size distribution, contaminant concentrations), oceanographic conditions (e.g., temperature, salinity, dissolved oxygen, ocean currents), and biological factors (e.g., food availability, competition, predation). For example, benthic assemblages on the coastal shelf of southern California typically vary along sediment particle size and/or depth gradients (Bergen et al. 2001). Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have an understanding of background or reference conditions for an area. Such information is available for the monitoring area surrounding the South Bay Ocean Outfall (SBOO) and the San Diego region in general (e.g., City of San Diego 1999, 2000; Ranasinghe et al. 2003, 2007).

This chapter presents analyses and interpretation of the macrofaunal data collected at fixed stations surrounding the SBOO during 2009. Descriptions and comparisons of the different macrofaunal assemblages that inhabit soft bottom habitats in the region and analysis of benthic community structure are included.

Materials and Methods

Collection and Processing of Samples

Benthic samples were collected during January and July 2009 at 27 stations surrounding the SBOO located along the 19, 28, 38, or 55-m depth contours (Figure 5.1). Four stations considered to represent "nearfield" conditions herein (i.e., I12, I14, I15, I16) are located between 35 and 600 m of the outfall wye or diffuser legs.

Samples for benthic community analyses were collected from two replicate 0.1-m^2 Van Veen grabs per station during each survey. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria to ensure consistency of grab samples established by the United States Environmental Protection Agency (U.S. EPA) were followed with regard to sample disturbance and depth of penetration (U.S. EPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were collected and

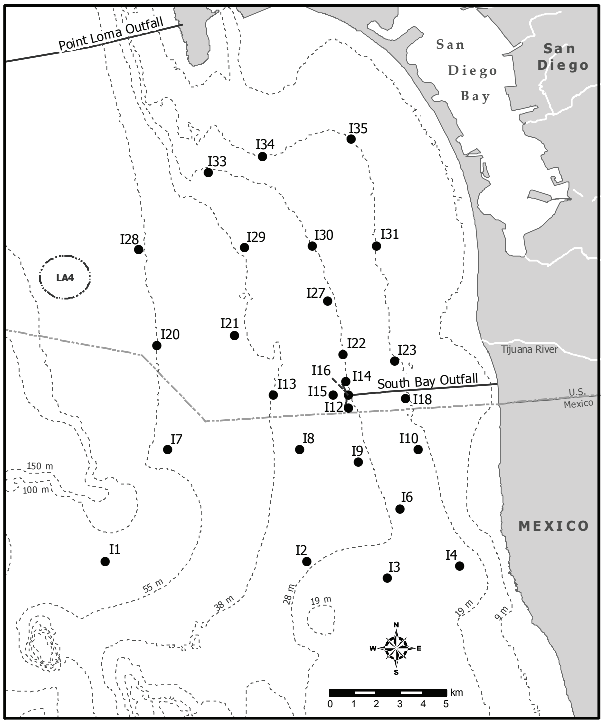

Figure 5.1
Benthic station locations sampled for the South Bay Ocean Outfall Monitoring Program.

relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted from the debris into major taxonomic groups by a subcontractor and then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

The following community structure parameters were calculated for each station per 0.1-m^2 grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (Swartz et al. 1986, Ferraro et al. 1994), and the benthic response index (BRI; Smith et al. 2001). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

Multivariate analyses were performed using PRIMER software to examine spatio-temporal patterns in the overall similarity of benthic assemblages (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). The macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Similarity profile (SIMPROF) analysis was used to confirm non-random structure of the dendrogram (Clarke et al. 2008). Similarity percentages (SIMPER) analysis was used to identify individual species that typified each cluster group. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physico-chemical data onto MDS plots based on the biotic data (Field et al. 1982, Clarke and Ainsworth 1993).

Results and Discussion

Community Parameters

Species richness
A total of 762 macrobenthic taxa (mostly species) were identified during the 2009 SBOO surveys. Of these, approximately 23% ($n = 178$) represented rare taxa that were recorded only once. Mean values of species richness ranged from 37 taxa per 0.1 m^2 at station I18 to 129 taxa per 0.1 m^2 at station I28 (Table 5.1). Average values for the other 25 stations ranged from 47–120 taxa per 0.1 m^2. This wide variation in species richness is consistent with patterns seen in previous years, and can probably be attributed to the presence of different habitat or microhabitat types in the region (see City of San Diego 2006–2009). Higher numbers of species, for example, have typically occurred at stations such as I28 and I29 (e.g., City of San Diego 2009). However, overall species richness remained similar to last year, averaging only 1% higher in 2009 versus 2008. Although species richness varied spatially, there were no apparent patterns relative to distance from the outfall (Figure 5.2A).

Macrofaunal abundance
A total of 38,259 macrofaunal individuals were counted in 2009 with mean abundance values ranging

Table 5.1

Summary of macrobenthic community parameters for SBOO stations sampled during 2009. SR = species richness (no. species/0.1 m^2); Tot Spp = cumulative no. species for the year; Abun = abundance (no. individuals/0.1 m^2); H' = Shannon diversity index; J' = evenness; Dom = Swartz dominance; BRI = benthic response index. Data are expressed as annual means ($n = 4$) except Tot Spp ($n = 1$).

Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI
19-m Stations							
I35	90	174	434	3.5	0.79	25	31
I34	54	147	405	2.4	0.60	7	14
I31	63	133	235	3.3	0.80	21	20
I23	78	203	375	3.5	0.82	22	21
I18	37	93	144	2.7	0.82	11	20
I10	52	115	162	3.3	0.83	17	21
I4	51	141	199	3.1	0.80	16	10
28-m Stations							
I33	114	232	577	3.7	0.78	29	27
I30	69	150	239	3.7	0.87	26	25
I27	75	157	263	3.6	0.85	25	22
I22	104	224	462	3.7	0.79	27	23
I14	86	179	334	3.6	0.81	26	23
I16	71	179	296	3.3	0.81	23	27
I15	92	200	757	2.6	0.59	12	21
I12	107	219	467	3.7	0.79	29	22
I9	106	208	491	3.8	0.82	29	24
I6	63	139	496	2.6	0.63	10	15
I2	47	102	335	2.1	0.55	6	19
I3	50	116	358	2.4	0.62	9	15
38-m Stations							
I29	120	271	496	3.9	0.83	36	17
I21	60	131	263	3.3	0.81	17	6
I13	62	140	369	2.8	0.69	11	9
I8	61	132	431	2.7	0.65	11	18
55-m Stations							
I28	129	255	372	4.4	0.91	50	15
I20	59	142	186	3.3	0.82	21	6
I7	60	136	160	3.7	0.90	26	2
I1	74	170	263	3.5	0.83	24	13
Mean	75	112	354	3.3	0.77	21	18
Standard Error	3	4	19	0.1	0.01	1	1
Minimum	15	26	18	1.4	0.36	1	-1
Maximum	153	199	1415	4.6	0.97	59	36

from 144 to 757 animals per 0.1 m^2 sample (Table 5.1). The greatest number of animals occurred at station I15, which averaged 757 individuals per sample. In contrast, the fewest number of animals occurred at station I18 (144/0.1 m^2). Overall, there was a 15% decrease in total macrofaunal abundance between 2008 and 2009 (Figure 5.2B), with the greatest change occurring at station I6 (City of San Diego 2009).

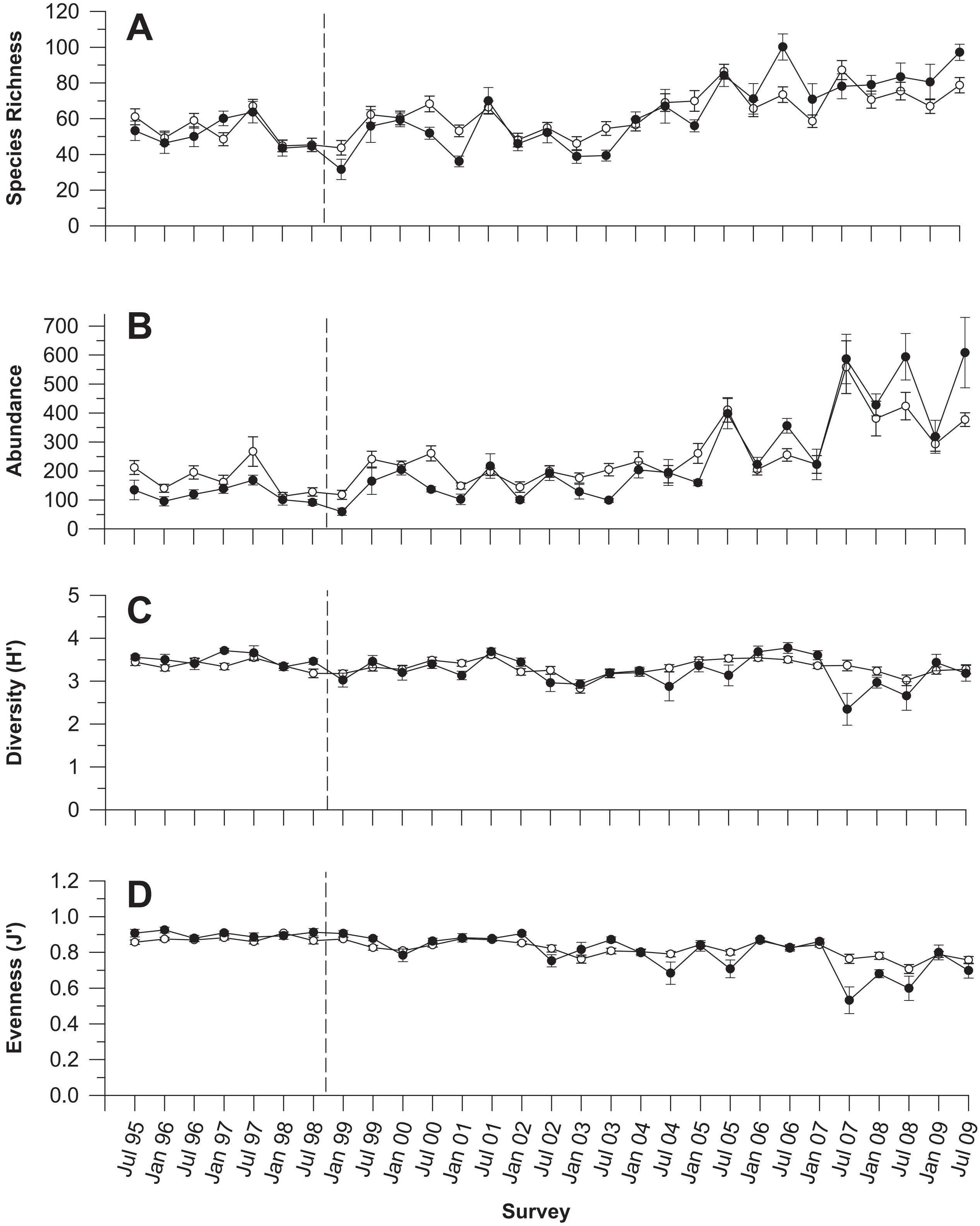

Figure 5.2

Summary of benthic community structure parameters surrounding the South Bay Ocean Outfall from 1995–2009: Species richness (no. of taxa); Abundance (no. of animals); Diversity = Shannon diversity index (H'); Evenness = Pielou's evenness index (J'); Swartz dominance index; BRI = Benthic response index. Data are expressed as means ± standard error per 0.1 m^2 pooled over nearfield stations (dark circles, $n = 8$) versus farfield stations (open circles, $n = 46$) for each survey. Dashed line indicates onset of discharge from the SBOO.

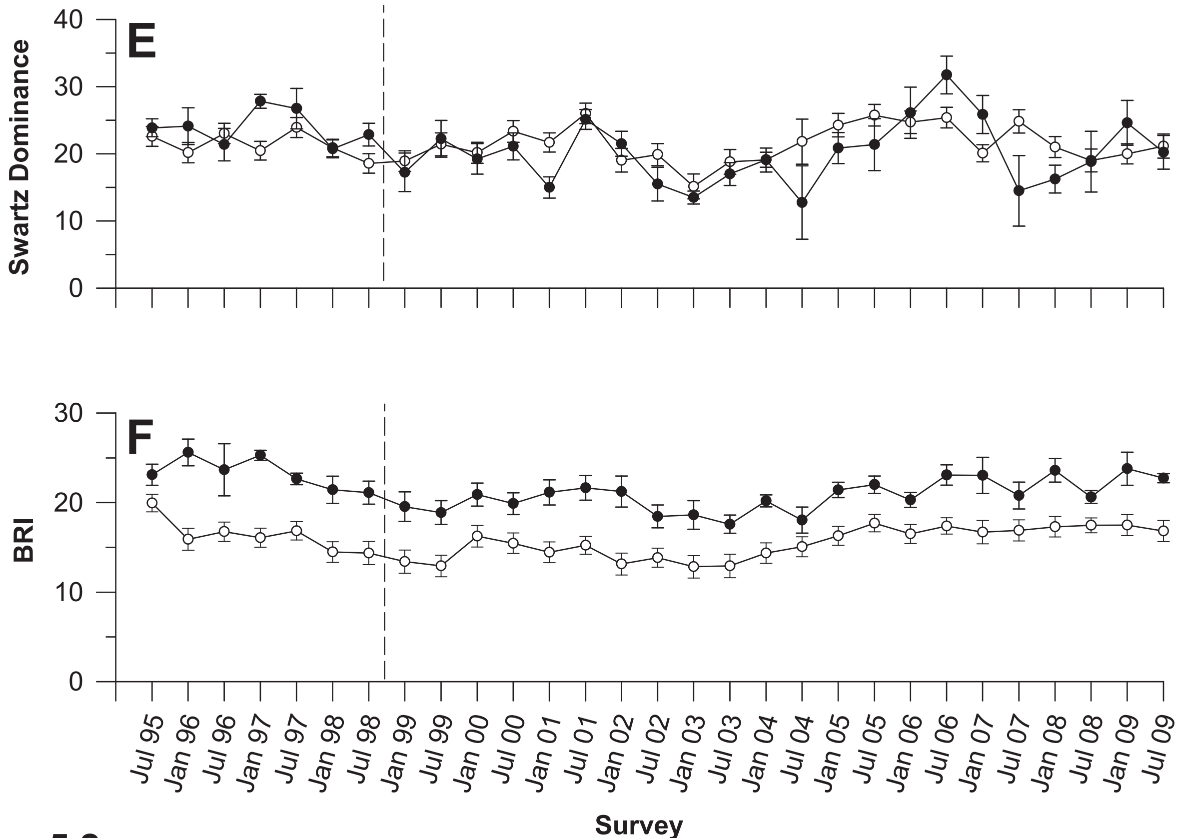

Figure 5.2 *continued*

Species diversity and dominance

Species diversity (H') averaged from 2.1 to 4.4 during 2009 (Table 5.1). Average diversity values in the region were generally similar to previous years, and there were no apparent patterns relative to distance from the outfall discharge site (Figure 5.2C). Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed (i.e., not dominated by a few highly abundant species). During 2009, J' values averaged between 0.55 and 0.91 with spatial patterns similar to those for diversity.

Dominance was expressed as the Swartz dominance index, which is calculated as the minimum number of taxa whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Therefore, lower index values (i.e., fewer taxa) indicate higher numerical dominance. Values at the individual SBOO stations averaged between 6 and 50 species per station during the year (Table 5.1). This range reflects the dominance of a few species at some sites (e.g., stations I2, I3, I34) versus other stations where many taxa contributed to the overall abundance (e.g., I28, I29). Overall, Swartz dominance values for 2009 were similar to historical values with no clear patterns evident relative to the outfall (Figure 5.2E).

Benthic Response Index

Benthic response index (BRI) values averaged from 2 to 31 at the various SBOO stations in 2009 (Table 5.1). Index values below 25 (on a scale of 100) are considered indicative of reference conditions, while those between 25 and 34 represent "a minor deviation from reference conditions" that should be confirmed by additional sampling (Smith et al. 2001). Stations I16, I33, and I35 were the only stations with mean BRI values above 25 (i.e., 27, 27, and 31, respectively), although there was no gradient relative to distance from the outfall. The index value for one grab sample collected at I16 (~40 m from the outfall wye) in January did appear to deviate from reference conditions (i.e., BRI = 36). A BRI value of 36 may begin to reflect a reduction or loss in biodiversity. Although the cause of this higher than normal BRI value is not clear, results of sediment analyses indicated that the sample was characterized by unusually fine sediments (i.e., 80% fines), as well as some elevated trace metals and organic indicator values (see Chapter 4). Additionally, the subsequent July sediment analyses showed no deviation from historical means.

Since monitoring first began in July 1995, mean BRI values at the four nearfield stations (I12, I14, I15, I16) have been higher than values for the farfield stations combined (Figure 5.2F). This pattern has remained consistent over time, including the period prior to January of 1999 when wastewater discharge was initiated through the SBOO. The difference is likely due to the effects of lower BRI values at the 38-m and 55-m stations on the farfield mean BRI (see Smith et al. 2001 for a discussion of the influence of depth on the BRI).

Dominant Species

Macrofaunal communities in the SBOO region were dominated by polychaete worms in 2009, accounting for 50% of all species collected (Table 5.2). Crustaceans accounted for 21% of the species, molluscs 15%, echinoderms 6%, and all other taxa combined for the remaining 8%. Polychaetes were also the most numerous animals, accounting for 73% of the total abundance. Crustaceans accounted for 12% of the animals, molluscs 8%, echinoderms 4%, and the remaining phyla 3%. Overall, the above distributions were very similar to those observed in 2008 (see City of San Diego 2009).

Table 5.2
The percent composition of species and abundance by major phyla for SBOO stations sampled during 2009. Data are expressed as annual means (range) for all stations combined; $n = 27$.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	50 (45–57)	73 (54–86)
Arthropoda (Crustacea)	21 (13–27)	12 (5–24)
Mollusca	15 (9–23)	8 (3–18)
Echinodermata	6 (3–9)	4 (2–9)
Other Phyla	8 (3–16)	3 (1–9)

Eight polychaetes, one crustacean, and one echinoderm were among the 10 most abundant macroinvertebrates sampled during the year (Table 5.3). The most abundant species collected was the spionid polychaete *Spiophanes norrisi* (reported as *S. bombyx* in previous reports), which occurred at 100% of the stations and averaged 88 (2–930) individuals per sample. While *S. norrisi* was ubiquitous in the SBOO region, abundances at individual stations varied considerably. For example, two stations (I15 and I6 in July) had much higher abundances of this species than the other sites, with a combined total of 2594 individuals. Overall, *S. norrisi* accounted for about 25% (i.e., 9520 individuals) of the macrobenthic fauna sampled during 2009 (see Figure 5.3).

Few other macrobenthic species were as widely distributed as *S. norrisi* (Table 5.3), with only eight taxa occurring in 80% or more of the samples. Five of the most frequently collected species also were among the top 10 most abundant taxa (i.e., *Spiophanes norrisi*, Euclymeninae sp A, *Spiophanes duplex*, *Mediomastus* sp, *Ampelisca cristata cristata*). In contrast, the amphinomid polychaete *Pareurythoe californica* was found in relatively high numbers at only two stations, I23 and I34 where sediments were comprised almost entirely of sand and coarse materials (i.e., shell hash).

Classification of Macrobenthic Assemblages

Results of the ordination and cluster analyses discriminated seven habitat-related macrobenthic assemblages (Figure 5.4, 5.5). These assemblages (cluster groups A–G) varied in terms of their species composition (i.e., specific taxa present) and the

Table 5.3

The 10 most abundant macroinvertebrates collected at the SBOO benthic stations sampled during 2009. Abundance values are expressed as mean number of individuals per 0.1-m² grab sample.

Species	Higher Taxa	Percent Occurrence	Abundance per Sample	Abundance per Occurrence
Most Abundant				
Spiophanes norrisi	Polychaeta: Spionidae	100	88.1	88.1
Monticellina siblina	Polychaeta: Cirratulidae	67	15.0	22.5
Euclymeninae sp A	Polychaeta: Maldanidae	87	9.7	11.1
Spiophanes duplex	Polychaeta: Spionidae	76	9.1	12.0
Notomastus latericeus	Polychaeta: Capitellidae	74	8.0	10.8
Mooreonuphis nebulosa	Polychaeta: Onuphidae	41	6.9	16.9
Mediomastus sp	Polychaeta: Capitellidae	85	5.2	6.1
Spiophanes berkeleyorum	Polychaeta: Spionidae	70	3.9	5.6
Ampelisca cristata cristata	Crustacea: Amphipoda	80	3.8	4.8
Ophiuroconis bispinosa	Echinodermata: Ophiurodia	63	3.8	6.0

relative abundance of those species, and occurred at sites separated by different depths and/or sediment microhabitats (Figure 5.6). The SIMPROF procedure indicated statistically significant non-random structure among samples ($\pi = 6.92$, $p < 0.001$), and an MDS ordination of the station/survey entities supported the validity of the cluster groups (Figure 5.4B). SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, of some assemblages; i.e., the three most characteristic species for each cluster group are indicated in Figure 5.4A. A complete list of species comprising each group and their relative abundances can be found in Appendix D.1.

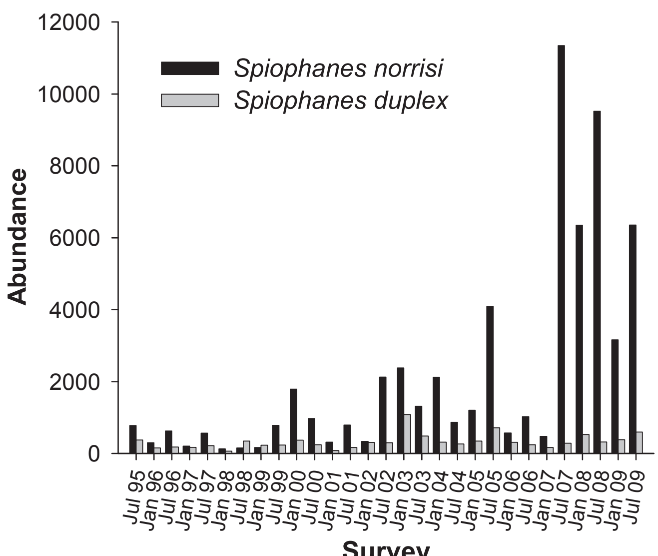

Figure 5.3

Total abundance of the polychaetes *Spiophanes norrisi* and *Spiophanes duplex* for each survey at the SBOO benthic stations from 1995–2009.

Cluster group A represented a shallow-shelf assemblage that occurred in January at station I18, which is located along the 19-m depth contour. This assemblage contained only 16 taxa and 21 individuals per 0.1 m², the lowest among all cluster groups. Juvenile ophiuroids *Amphiodia* sp, were present in this group, as were the polychaete Euclymeninae sp A and the ostracod *Euphilomedes carcharodonta*. The sediments characteristic of this sample contained the highest amounts of percent fines (44%) compared to the other group averages (i.e., 2–21%), and had a total organic carbon (TOC) concentration of 0.3% weight (% wt).

Cluster group B represented a shallow-shelf assemblage restricted to the January surveys at stations I34 and I23. This group was associated with very coarse sediments comprised almost entirely of sand and shell hash (i.e., only 7% fines). Although TOC concentrations tend to correlate with percent fines (see Chapter 4), TOC values for these two samples were relatively high at 2.8% wt on average. Species richness averaged 57 taxa and abundance averaged 341 individuals per 0.1 m². As in previous years (see City of San Diego 2007, 2009), this unique assemblage

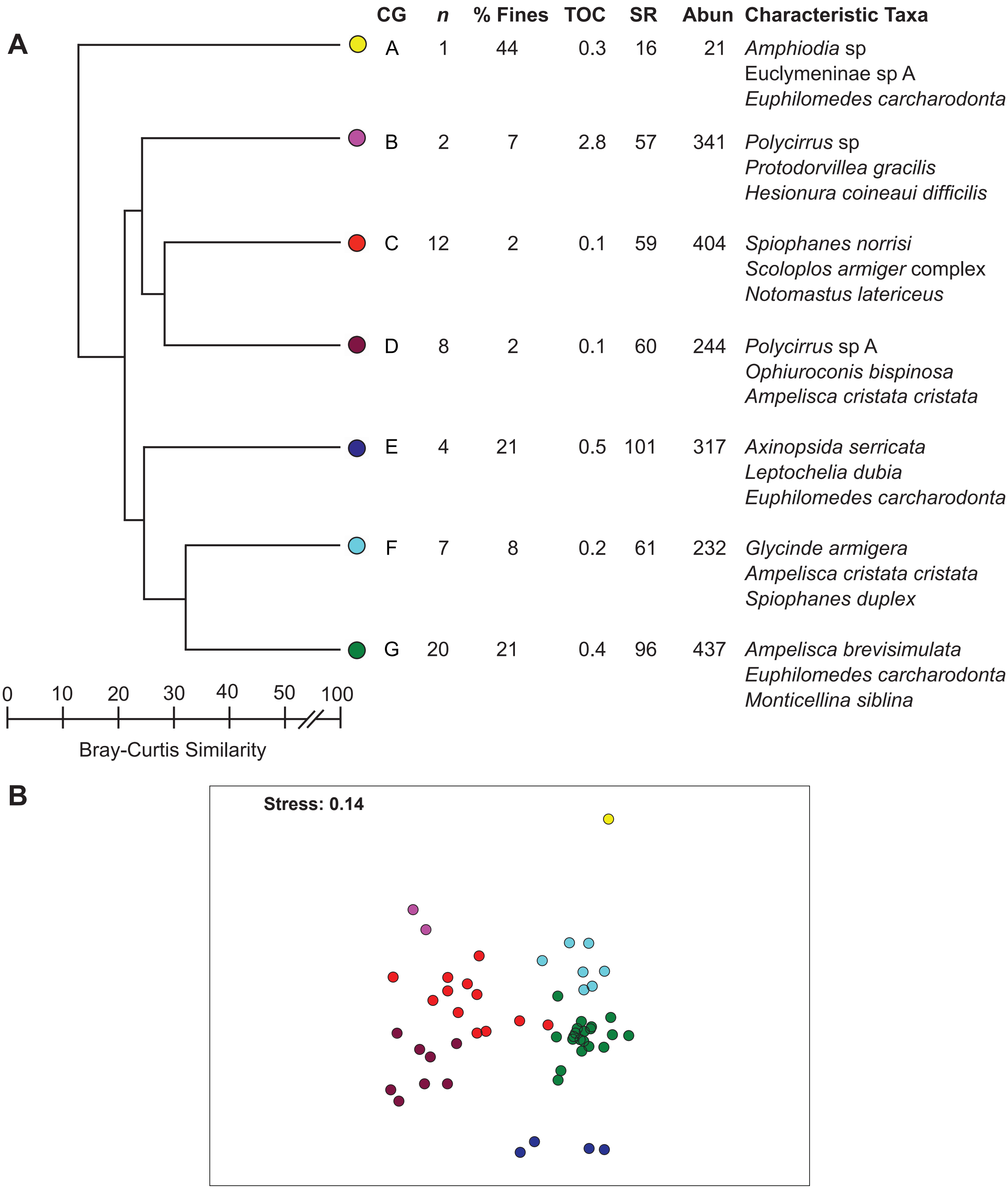

Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the SBOO benthic stations sampled during winter and summer 2009. Data for percent fines, total organic carbon (TOC; % weight), species richness (SR), and infaunal abundance (Abun), are expressed as mean values per 0.1-m^2 grab over all stations in each group (CG). (B) MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

contained several polychaete species commonly found in sediments with coarse particles (e.g., *Hesionura coineaui difficilis*, *Hemipodia borealis*, and *Pisione* sp). The cephalochordate, *Branchiostoma californiense*, also associated with coarse sediment habitats, was present as well (Appendix D.1).

Cluster group C represented an assemblage that occurred at eight stations located mostly near the discharge site or south of the outfall at depths between 18–36 m. This assemblage averaged 59 taxa and 404 organisms per 0.1 m^2. Polychaetes were numerically dominant, with the spionid *Spiophanes norrisi,* the orbiniid *Scoloplos armiger* complex, and the capitellid *Notomastus latericeus* representing the three most characteristic taxa. The habitat at these sites was characterized by mixed but coarse sediments, especially red relict sand, with TOC values that averaged 0.1% wt.

Cluster group D represented an assemblage characteristic of four sites east of the SBOO located along the 38 and 55-m depth contours. This assemblage averaged 244 individuals and 60 taxa per 0.1 m^2. The three most characteristic species of this group were the terebellid polychaete *Polycirrus* sp A, the ophiuroid *Ophiuroconis bispinosa* and the amphipod *Ampelisca cristata cristata.* Sediments at these sites were comprised of red relict sands and averaged only 2% fines with TOC values of 0.1% wt on average.

Cluster group E represented a mid-shelf assemblage from stations located near the 55-m depth contour. This assemblage averaged 317 individuals and 101 taxa per 0.1 m^2, the latter representing the highest species richness for the region. The three most characteristic species included the thyasirid bivalve *Axinopsida serricata,* the tanaid *Leptochelia dubia* and the ostracod *E. carcharodonta*. The sediments associated with this group were mixed, composed of 21% fines and some coarse black sand with TOC values of 0.5% wt on average.

Cluster group F represented the shallowest overall assemblage sampled at five sites along the 19-m contour. Abundance averaged 232 individuals and species richness averaged 61 taxa per 0.1 m^2. The three most characteristic species in this assemblage were the goniadid polychaete *Glycinde armigera*, the amphipod *A. cristata cristata*, and the spionid polychaete *Spiophanes duplex*. Sediments at this site were relatively coarse (8% fines) and contained shell hash and organic debris with an average TOC value of 0.2% wt.

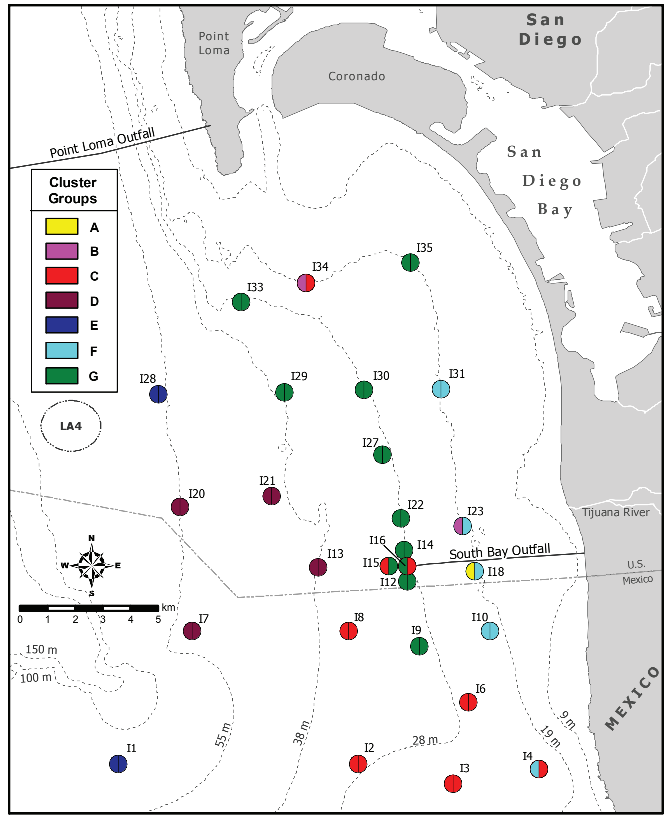

Figure 5.5
Spatial distribution of SBOO macrobenthic assemblages delineated by ordination and classification analyses (see Figure 5.4). Left half of circle represents cluster group affiliation for the January survey; right half represents the July survey.

Cluster group G represented the most wide-spread macrobenthic assemblage present in 2009, comprising animals from 37% of the samples and 11 stations located mainly along the 19 and 28-m depth contours. This shallow shelf assemblage averaged 96 taxa and 437 individuals per 0.1 m^2. The top three characteristic species included the amphipod *Ampelisca brevisimulata*, the ostracod *E. carcharodonta*, and the cirratulid *Monticellina siblina*. The sediments associated with this assemblage

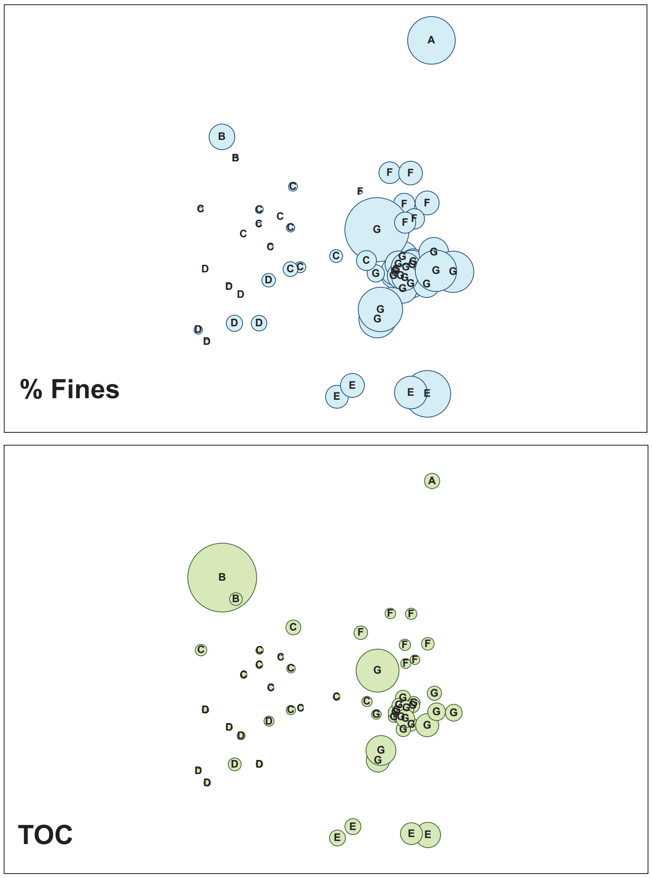

Figure 5.6
MDS ordination of SBOO benthic stations sampled during winter and summer 2009. Cluster groups A–G are superimposed on station/surveys. Percentages of fine particles and total organic carbon (TOC) in the sediments are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size and TOC. Stress = 0.14.

were characterized by some shell hash and 21% fines with TOC values of 0.4% wt on average.

Summary and Conclusions

Benthic macrofaunal assemblages surrounding the SBOO were similar in 2009 to those that occurred during previous years, including the period before initiation of wastewater discharge (e.g., see City of San Diego 2000, 2009). In addition, these assemblages were typical of those occurring in other sandy, shallow-, and mid-depth habitats throughout the Southern California Bight (SCB) (e.g., Thompson et al. 1987, 1993b; City of San Diego 1999, Bergen et al. 2001, Ranasinghe et al. 2003, 2007). For example, assemblages found at the majority of stations (i.e., cluster groups C and G) contained high numbers of the spionid polychaete *Spiophanes norrisi*, a species characteristic of shallow-water environments with coarser sediments in the SCB (see Bergen et al. 2001). These two groups represented sub-assemblages of the SCB benthos that differed in the relative abundances of dominant and co-dominant species. Such differences probably reflect variation in sediment structure. Consistent with historical values, sediments in the shallow SBOO region generally were coarser south of the outfall relative to the more northern stations (see Chapter 4).

In contrast, the group E assemblage occurs in mid-depth shelf habitats that probably represent a transition between the shallow sandy sediments common in the area and the finer mid-depth sediments characteristic of much of the SCB mainland shelf (see Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1993a, EcoAnalysis et al. 1993, Diener and Fuller 1995). The group B assemblage, restricted to stations I34 and I23, was different from assemblages found at any other station. Several species of polychaete worms (i.e., *Pareurythoe californica*, *Typosyllis* sp SD1, *Hemipodia borealis, Hesionura coineaui difficilis*, *Micropodarke dubia*, and *Pisione* sp) not common elsewhere in the region were characteristic of this assemblage. This pattern is similar to that observed previously at these stations from 2003 through 2008 (see City of San Diego 2004–2009). Analysis of sediment quality data provides some evidence relevant to explaining the occurrence of the B assemblage, which represented only the January samples from the above two stations and where associated sediments were relatively coarse (see Chapter 4).

Results from multivariate analyses revealed no clear spatial patterns relative to the ocean outfall. Comparisons of the biotic data to the physico-chemical data suggest that macrofaunal distribution and abundance in the region varied primarily along depth and sediment gradients and to a lesser degree, TOC levels (see Hyland et al. 2005). Populations of the spionid polychaete *Spiophanes norrisi* collected during 2009 were the third highest recorded since monitoring began in 1995. Consequently, the high numbers for this species influenced overall abundance values in the region. Patterns of region-wide abundance fluctuations over time appear to mirror historical patterns of *S. norrisi* while temporal fluctuations in the populations of this and similar species occur elsewhere in the region and may correspond to large-scale oceanographic conditions (see Zmarzly et al. 1994). Overall, analyses of temporal patterns suggest that the benthic community in the South Bay region has not been significantly impacted by wastewater discharge. For example, while species richness and total macrofaunal abundance were at or near their historical highs during 2009, annual means from the four nearfield stations were similar to those located further away (see City of San Diego 2006–2009). Diversity (H') and evenness (J') values have also remained relatively stable since monitoring began in 1995. In addition, environmental disturbance index averages such as the BRI continue to be generally characteristic of assemblages from undisturbed habitats.

Annual means of macrofaunal parameters help to give an integrated view of community health, but can sometimes mask anomalous samples at an individual station. For example, one sample from station I16 in January was relatively depauperate of taxa (i.e., 7 taxa and 39 individuals) with a resulting BRI value of 36, though macrofaunal parameters from a replicate sample taken on the same day fell within normal ranges (i.e., 6 taxa, 242 individuals, and BRI = 23). The differences between these two samples could be accounted for by sediment habitat heterogeneity at relatively small spatial scales (i.e., meters). Sediment habitats can change over time as well. For example, sediments at I16 in January differed markedly from July and from historical values, with the depauperate sample sieved from sediments containing mostly silt (see Chapter 4). Station I18 in January also contained historically high fines, low species richness and low infaunal abundance compared to typical values.

Anthropogenic impacts are known to have spatial and temporal dimensions that can vary depending on a range of biological and physical factors. Such impacts can be difficult to detect, and specific effects of the SBOO discharge on the local macrobenthic community could not be identified during 2009. Furthermore, benthic invertebrate populations exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, b; Otway 1995). Although some changes have occurred near the SBOO over time, benthic assemblages in the area remain similar to those observed prior to discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf.

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